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ON THE ANTHROPOMETRIC LABORATORY

AT THE LATE

INTERNATIONAL HEALTH EXHIBITION.

BY

FRANCIS GALTON, M.A., F.R.S.

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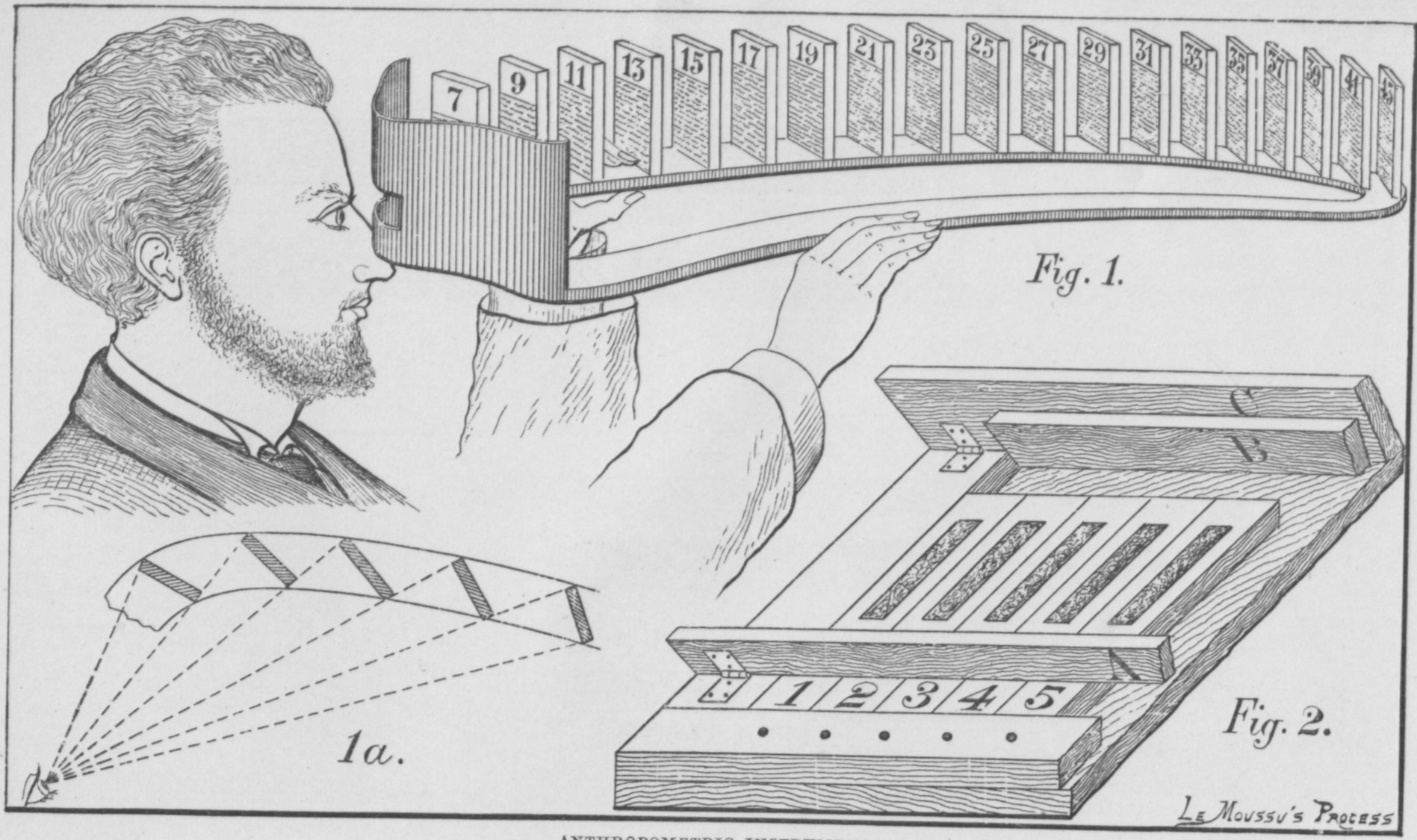

Fig. 1.

1a.

Fig. 2.

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ANTHROPOMETRIC INSTRUMENTS.

Journ. Anthrop. Inst., Vol. XIV, Pl. XII.

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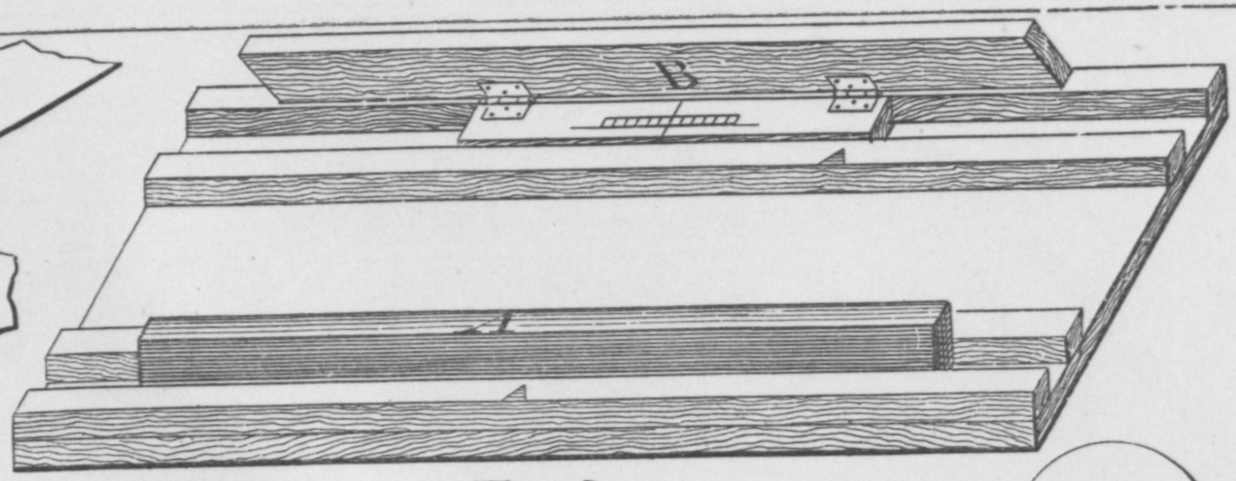
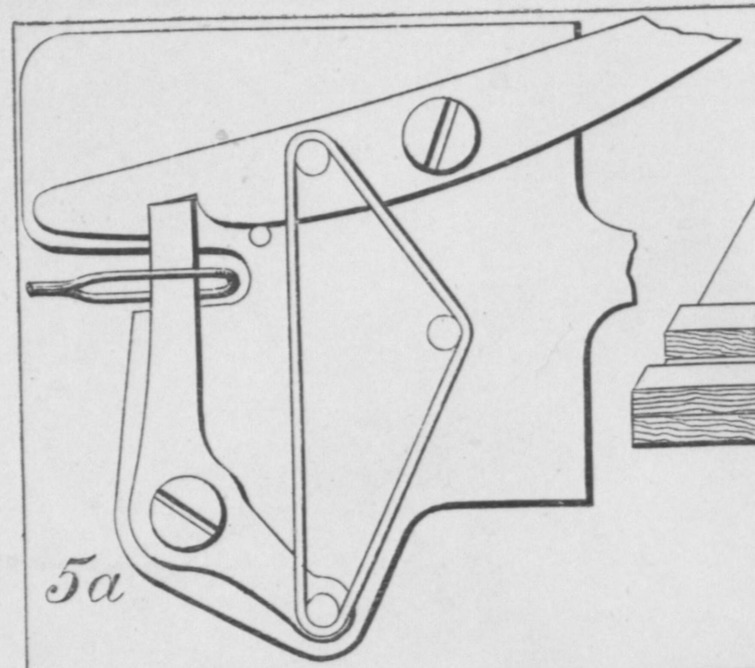


Fig. 3.



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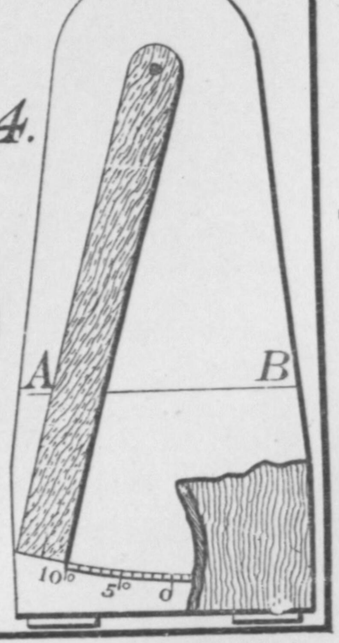

Fig. 4.

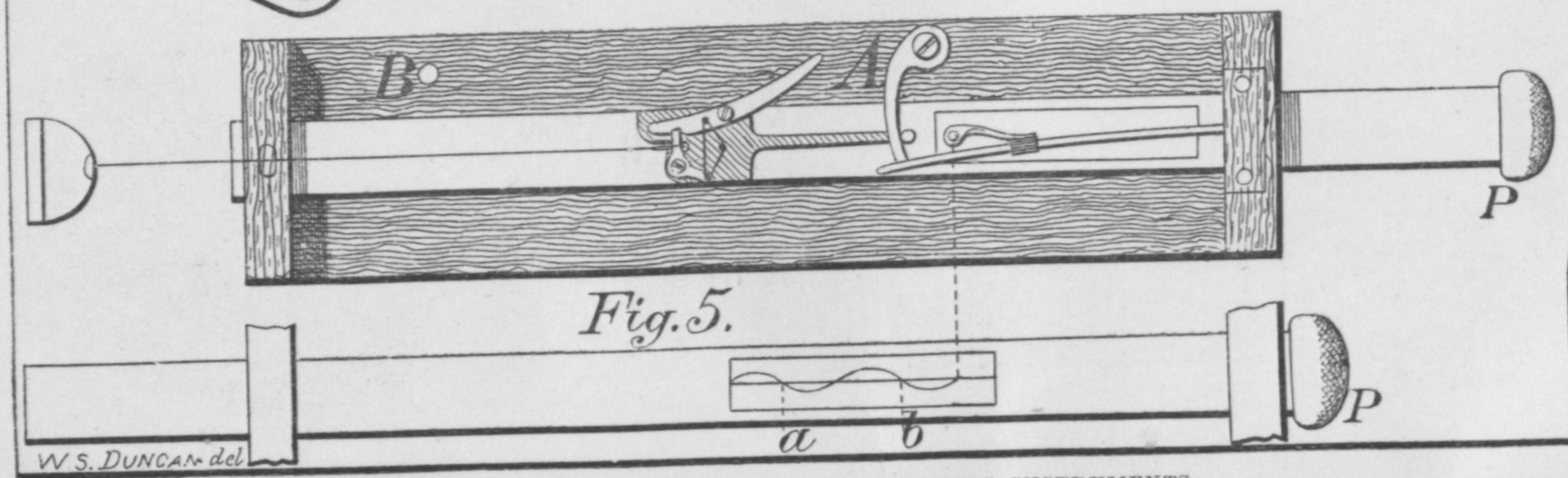

Fig. 5.

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ANTHROPOMETRIC INSTRUMENTS.

Journ. Anthrop. Inst., Vol XIV, Pl. XIII.

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PAPERS

On the Anthropometric Laboratory *at the late* International Health Exhibition. By Francis Galton, M.A., F.R.S.

[With Plates XII and XIII.]

Now that the International Health Exhibition is over, and the Anthropometric Laboratory there established has done its appointed work, it is desirable to put on record its methods and experiences. As for the statistical results they are still under discussion and I shall not speak of them now, but I hope before long to communicate these also to the Institute.

The object of the laboratory was to show to the public the simplicity of the instruments and methods by which the chief physical characteristics of man may be measured and recorded. The instruments in action dealt with keenness of sight; colour-sense; judgment of eye; hearing; highest audible note; breathing power; strength of pull and squeeze; swiftness of blow; span of arms; height, standing and sitting; and weight. Some other apparatus not in actual use was also exhibited.

The chief motive of this memoir is to invite criticism and

suggestions. Duplicates of the instruments have been ordered by executive officers in foreign countries, and considerable interest has been expressed in the collection by the authorities of many places of education in this country, as well as by numerous private individuals. It seems, therefore, well to lose no time in considering whether any and what improvements should be made in their scope and design before they or any others may be so widely used that it would become difficult to make a change. We want a set of standard apparatus of as appropriate a pattern as can be devised, for the sake of uniformity in the methods of measurement and facility in statistical comparisons. I have therefore brought all my instruments to this room, together with the attendants who had charge of them in the Exhibition, availing myself very gladly of the opportunity afforded by this meeting of submitting my method and appliances to discussion.

The number of persons measured in the laboratory from first to last was no less than 9,337, and each of them in 17 different ways. The only attendants were Serjeant Williams, who was permanently on duty, Mr. Gammage (optical instrument maker, 172, Brompton Road), who came for some hours every evening to assist and supervise, and who maintained the instruments in efficiency, and a doorkeeper provided by the executive, who admitted visitors, received the admission fee of 3*d*., supplied the blank forms, and saw that the required particulars were written down by them. The doorkeeper also made himself useful in many other details. With this small staff, and in a compartment only 6 feet wide and 36 feet long, about ninety persons were measured daily in an elaborate manner.

It was not possible to work so rapidly at first, but the process gradually improved. Thus it was found best to take two persons through the laboratory together at the same time, and to keep parents and their children apart, as the old did not like to be outdone by the young, and insisted on repeated trials.

Hardly any trouble occurred with the visitors, though on some few occasions rough persons entered the laboratory who were apparently not altogether sober. On the whole, the laboratory worked with astonishing smoothness, and its popularity was extraordinary. Its door was thronged by applicants waiting patiently for their turn, or after a while turning away seeing that it was almost a hopeless task to wait. If there had been more accommodation there would have been a large increase in the number measured. The small admission fee of 3*d*. did more than cover every charge connected with the maintenance of the laboratory and I have therefore little doubt that a smaller number of careful measurements might be made periodically at

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large schools under skilled supervision for a very minute charge per head, if the system of doing so was well methodised, and if the masters, older pupils, and school attendants gave willing help.

There is a vast field for work among the millions of school boys and girls of all degrees, with the object of keeping an adequate oversight upon their physical well-being by a judicious series of physical measurements. I do not see why it should be either difficult or costly to the schools of the upper and middle classes, to whom a charge of two or three pence per head is a matter of no moment whatever, to institute periodical measurements even of a somewhat elaborate character under skilful itinerant supervision, and to register them in a methodical and uniform manner. It should, I think, become a recognised part of school discipline to have this regularly done; the more so as the experience of this laboratory, confirmed by those of many American colleges, makes it certain that the innovation would be popular. One of the conditions that a standard set of instruments ought to fulfil is, that it should admit of being readily packed, carried about from place to place, and quickly set up anywhere for temporary use by a professional measurer.

We have now to consider what we should measure. One object is to ascertain what may be called the personal constants of mature life. This phrase must not be taken in too strict a sense, because there is nothing absolutely constant in a living body. Life is a condition of perpetual change. Men are about half an inch shorter when they go to bed than when they rise in the morning. Their weight is affected by diet and habit of life. All our so-called personal constants are really variables, though a large proportion of their actual variations may lie between narrow limits. Our first rule then is, that the trouble of measurement is best repaid when it is directed upon the least variable faculties.

There are many faculties that may be said to be potentially constant in adults though they are not developed, owing to want of exercise. After adequate practice, a limit of efficiency would in each case be attained, and this would be the personal constant; but it is obviously impossible to guess what that constant would be from the results of a single trial. No test professes to do more than show the efficiency of the faculty at the time it was applied, and many tests do even less than this, being so novel to the person experimented on that he is maladroit, and fails to do himself justice; consequently the results of earlier trials with ill-devised tests may differ considerably from those of later ones. The second rule then is, that the actions required by the tests should be as familiar as possible.

For example, in testing the delicacy of the various senses I think we should do wrong if we pursued the strict methods appropriate to psycho-physical investigations. We do not want to analyse how much of our power of discriminating between two objects is due to this, that, or the other of the many elementary perceptions called into action. It is the total result that chiefly interests us. Thus in measuring the delicacy with which a person can estimate the difference between weights, I think he ought to be allowed to handle them in the way he prefers and that we may disregard the fact that his judgment rests on a blend of many different data, such as pressure, muscular exertion, and appreciation of size.

There is some hope that we may in time learn to eliminate the effect of an unknown amount of previous practice by three or more distinct sets of trials. There exists a rough relation between practice and proficiency which ought to be apparent wherever progress is not due to acquiring a succession of new knacks, but proceeds regularly. When no practice has previously taken place, the progressive improvement will be very rapid; then its rate will smoothly decrease until it comes to an entire stop. I suspect that a curve might be drawn, representing the relation between proficiency and practice, and that the data afforded by at least three successive series of tests would roughly determine the position in the curve of the person who was being tested. They would show what he was capable of at the time, and approximately how much conscious or unconscious practice he had already gone through, and the maximum efficiency to which his faculty under test admitted of being educated.

An ideally perfect laboratory, whether a plain or an elaborate one, would admit of a stream of persons passing continuously through it. There would be no gaps and no blocks by the way, because the number of such instruments as might necessitate two, three, or more units of delay would be multiplied in that proportion. Again, there would be no waste of the attendant's time in idly watching examinees puzzling over tests that required a prolonged judgment, because those tests would be so contrived that the examinee might be left to himself until he had performed the specified act, after which the attendant would return and note the result. To exemplify what I mean, I will describe the test (Plate XII, fig. 2) for colour-sense by the use of wools, which is further explained on p. 215. A set of Holmgren's patterns were wound each through two holes in a separate rod, much as a net maker winds string on his netting needle, and each rod had a separate number stamped on it. A row of these rods were laid in any order side by side in a frame, with a long narrow flap above and below.

When the flaps were shut, the rods were nipped fast and their numbers were hid; when the lower flap was opened the numbers were exposed. The test consisted in telling the examinee that there were four tints of green, and he was required to point them out. Then the lower flap was opened, and the truth of his choice was tested by the correctness of the exposed numbers.

If this had been the process pure and simple, the test would have occupied an undue amount of the attendant's time, who would have had to stand by doing nothing while the examinee was hesitating. It is probable that two minutes might have been so wasted, in which case the ninety persons who daily required between them about thirteen hours of direct supervision in performing seventeen tests, would have required twice ninety minutes, or three hours, for this test alone. Such a sacrifice would have been inadmissible and it was easily avoided by a simple contrivance. Holes were bored below the bottom flap, one opposite to each rod, and four pegs were tied to the instrument. The attendant directed the examinee to put a peg into the hole opposite to each of the four greens, and then left him to ponder over his task at leisure, while he attended to others. After awhile the attendant returned, found the pegs set, and noted the result in a couple of seconds.

A similar plan was adopted in two instruments (Plate XIII, figs. 3 & 4) that I used, less for the intrinsic value of their results than as examples of the way in which a large class of tests might be methodised. They were to test the judgment of the eye in dividing a line into equal parts and in estimating squareness. The accuracy of the result was in each case measured by graduations that were hidden under a closed flap, while the examinee was left by himself to make the required adjustments. Here, again, the examiner returned after awhile, and noted the results of a prolonged pondering in a very few seconds.

On this principle very elaborate tests might be introduced into a well furnished laboratory without adding to the cost of the course by taking up the valuable time of a skilled supervisor, or of diminishing the rate at which applicants might be admitted. The stream of them would still pass regularly through, but the length of the stream included between the entrance and the exit doors would be longer.

It will be remembered that in the laboratory at the Exhibition, ninety persons passed through daily, and that the amount of skilled attendance given to them amounted in the aggregate to about thirteen hours: that is, seven minutes to each. But the time each person was occupied in the laboratory was fully twenty-one minutes, and often half-an-hour. In the first place, the persons to be tested were taken in pairs, that one explanation

and illustration might suffice for both, and since the promptest minded man of the two was usually the one who presented himself first, the less prompt man had the advantage of seeing his companion perform the test before he was called upon to do so himself. This duplex system changed the seven minutes into fourteen. Then there was the time occupied by each examinee in reading notices, writing down particulars of his age, state, occupation, and birth-place, in puzzling alone over set tasks, and in amusing himself by watching others.

I have dwelt at length on this because the necessity of labour-saving arrangements must be carefully borne in mind when devising a standard laboratory outfit, in which a large number of persons may be elaborately measured at a minimum of cost.

In the Appendix to this paper will be found a brief but sufficient description of the instruments used in the laboratory. I will now call attention only to those points which appear especially in need of criticism.

One omission in the laboratory has been noticed by many. I had decided, perhaps wrongly, after much hesitation, not to measure the head. My reason was, that the results would, under the peculiar circumstances of a mixed crowd of persons, each measured only once, be of little or no profit, and I feared it would be troublesome to perform on most women on account of their bonnets, and the bulk of their hair, and that it would lead to objections and difficulties. In the case of periodical measurements at schools, the head measurement would be of primary importance, and I should propose to take its maximum length and breadth with graduated calipers, and its maximum height above the plane that passes through the upper edges of the orbits and the orifices of the ears.[1]

I measured the chief dimensions of the body, the weight and the breathing capacity, but could devise no good method, other than what these implicitly afford, of ascertaining the bulk, and its distribution in muscle or fat. Stripping was of course inadmissible, and measurements of girth, whether of body or limb, taken over the clothes, are rather fallacious. The excess due to the presence of the clothes, and supposing no wrinkles, is six times their thickness, taking the circumference of the limb as equal to six times its mean radius. The wrinkles add an unknown amount to the error.

For the first time such a thing has been attempted, I measured swiftness of blow as distinguished from force of blow, the latter

[1] I have designed and made the necessary instruments since this memoir was read. They are now being constructed solidly for me by the Scientific Instrument Company at Cambridge, and they will be in use at Cambridge in the beginning of 1885.

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of which is a compound result of swiftness, weight, and knack. The instrument was based upon a very pretty principle first applied by Exner in his little apparatus for measuring reaction-time. It was a matter of surprise to myself, who was born in the days of pugilism, to find that the art of delivering a clean hit, straight from the shoulder, as required by this instrument, is nearly lost to the rising generation. My instrument (Plate XIII, fig. 5) consisted of a rod, padded at one end, and running quite freely between guides. The person to be tested was asked to hit the pad which fronted him, and to drive the bar forwards with as much swiftness as he could. The rate of progress of the rod was marked by a pencil attached to a vibrating spring that had been bent to one side and was retained by a catch to be set free by the moving rod. Notwithstanding the simplicity of the test, a large proportion of persons bungled absurdly over it. They could not or would not strike straight at the pad, but punched its side, and often broke the rod and hurt their knuckles. I had the deal rod replaced by an oaken one, and they still broke it and hurt their knuckles all the more. I then, in despair, reversed the action, by passing the looped end of a string round a catch (fig. 5*a*), forming part of an apparatus that was fixed to the opposite end of the rod, and I attached a stirrup to the other end of the string which the examinee held in his hand while he struck out into space, pulling the rod after him. While the rod was in motion, and before it was pulled home, the free end of the lever that retained the catch struck against a peg B in the frame of the apparatus; the catch was thereby released and the string (or rather the steel wire, which I used at last) was disengaged, and there was nothing left to break. On this plan all went well. This instrument has given beautifully accordant results in successive trials, but I propose to supersede it by another pattern, not yet quite complete in details, but primarily consisting of a light hoop turning round a horizontal axis, the string disengaging itself as it does from a humming-top.

I employed only a few tests for the delicacy of the various senses, but many others might be added with advantage to a fully equipped laboratory if they were constructed on the labour-saving principle I have described.

The construction of an absolute and convenient test for delicacy of hearing, quite baffles me. I mean an apparatus that any instrument maker might construct from description, every specimen of which should emit a sound always of the same loudness and quality. Identity in the striking bodies may be ensured by using coins, and the arrangement of two pennies (that is two short cylinders) striking crossways is theoretically perfect as ensuring that the locus of contact shall be a point. But the

trouble is to hold the pence firmly and conveniently by rods, too slight to increase the sound either by echoes or by their own vibrations caused by the concussion. The rods should nip the pence at their nodal points so as not to hinder the vibrations. I should be very grateful for useful suggestions.

The sickle-shaped hand instrument (Plate XII, fig. 1) used for reading small test type, first with one eye and then with the other, acted excellently, but the light in the laboratory was often bad. I used pages cut out of the shilling diamond edition of the Prayer Book, because it was easily accessible, and to enable persons who had been tested at the laboratory to repeat the identical experiment at home with their friends. But printed sentences, especially when they are so generally well known as those in the Prayer Book, are objectionable: a page of logarithms would be much better.

I exhibited, but did not use, a model of a test for delicacy of touch, so far as pressure is concerned, which has merits, but would I feared have occupied too much time. It is a "Roberval" balance, like a common letter weigher; the finger is laid on one scale pan, and the object of the instrument is to increase or diminish the weight in the other pan with perfect smoothness and at any desired rate. I effected this by placing a light cylindical glass vessel, half filled with water, in the other scale pan, and suspended a broad plunger above it on the "Roberval" principle.

When the plunger was depressed, the water rose in the graduated glass cylinder, and the effect was exactly the same as if an equivalent amount of water had been poured in; conversely, the water sank when the plunger was raised. The action of the instrument seems perfect, but it exists as yet only as a working model.

A useful set of tests of judgment of absolute weights might be added, such as by requiring vessels to be filled with sand, till in the judgment of the examinee the one should weigh a pound, and the other an ounce, and then setting them in scales and recording the percentage of error. Similarly as regards absolute length, as by pulling out slides until they measured respectively a yard, a foot and an inch, and then opening a flap and displaying the test graduations in percentages of the yard, foot, and inch.

I will not take up time by describing other contrivances more or less promising that I have thought of but not actually used, and will now conclude by submitting the points on which I have dwelt to discussion, adding that I should also feel sincerely obliged by any helpful remarks that may be sent to me in writing.

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APPENDIX

(Chiefly extracted from the 1*d. book sold by Authority at the Exhibition).*

The object of the Anthropometric Laboratory is to show to the public the great simplicity of the instruments and method by which the chief physical characteristics may be measured and recorded. The instruments at present in action deal with Keenness of Sight; Colour-Sense; Judgment of Eye; Hearing; Highest Audible Note; Breathing Power; Strength of Pull and Squeeze; Swiftness of Blow; Span of Arms; Height, standing and sitting; and Weight.

Such is the ease of working the instruments that a person can be measured in all these respects, and a card containing the results furnished to him, while a duplicate is made and preserved for statistical purposes, at a total cost of 3*d.*

The use of periodical measurements is two-fold, personal and statistical. The one shows the progress of the individual; the other that of portions of the nation, or of the nation as a whole.

Description of the Laboratory.

A space 36 feet long by 6 feet wide is fenced off from the side of a gallery by open lattice work. It is entered by a door at one end, and is quitted by a second door at the other. The public can easily see through the lattice work, while they are prevented from crowding too close. A narrow table runs half-way down the side of the laboratory, on which the smaller instruments are placed. The measurements with the larger ones take place in the open space beyond the table.

The successive stations for the various operations lie in the following order:—

1. Desk at which the newly-entered person writes down certain data concerning himself.
2. Standard specimens for colour of eyes and hair.
3. Sight: (*a*) its keenness; (*b*) the colour-sense; (*c*) judgment of the eye in estimating length and squareness.
4. Hearing: (*a*) its keenness (scarcely practicable on account of the noise and echoes); (*b*) highest audible note.
5. Touch (exhibition of various apparatus).
6. Breathing capacity.
7. Swiftness of blow with fist.
8. Strength: (*a*) of pull; (*b*) of squeeze with right and with left hands.
9. Height: (*a*) when sitting, measured from the seat of the chair; (*b*) standing in shoes; (*c*) the thickness of the heel of the shoe.
10. Span of the arms.
11. Weight.

Process gone through.

1. THE DESK.—On payment of 3*d.* at the door, the applicant is admitted to the desk, and given a frame which contains a card, over which thin transfer paper is stretched. Carbonised paper is placed between them. Thus a duplicate copy of the entries is obtained, to be kept for statistical purposes. The card with the entries upon it is given to the person measured.

No names are asked for. The following plan is adopted to secure such data for the duplicate copy as are needful for its use as a statistical document, without annoying the applicant, who may be disinclined to parade his or her age, &c., on the card. The transfer paper is doubled over the back of the card, and no carbonized paper is put behind the flap; consequently what may be written upon it will not appear on the card. The particulars required on the flap are: Age last birthday; birthplace; state (married, unmarried, or widowed); residence, whether urban, suburban or country; occupation. All this takes place at the first station, which is partially curtained for the sake of privacy.

When these data have been written, the frame is turned over, and the other side is henceforth uppermost. On this the attendant marks the sex, and the applicant writes his initials or other distinguishing mark, to guard against any accidental interchange of the frames belonging to different persons who are simultaneously undergoing measurement.

At this same station is suspended a card, with specimens of wool of various shades of green worked upon it. Attention is directed to these specimens, that the applicant may clearly understand what will be required of him a few stations on, when his colour-sense is tested by his being asked to pick out all the green shades from among many wools of different colour. It is important that he should appreciate the wide variety of shades that are used, otherwise he may fail in the test, owing to a misunderstanding of what he is wanted to do.

2. COLOUR OF EYES AND HAIR.—Artificial eyes of standard colours are exhibited, together with the following descriptive names—dark-blue, blue, grey, dark-grey, brown-grey, (green, light hazel), brown, dark-brown, black. The attendant will note the colour of the eyes, but no entry will be made regarding the colour of the hair, for the reason that what with the darkening effects of pomades, and of dyes, and the misleading appearances of false hair, no useful results could be arrived at. However, for the convenience of the visitor, samples of standard colour of hair are exhibited, and the names are attached by which the chief varieties of colour are usually described. They are flaxen, light-brown, brown, dark-brown, fair red (golden), red, dark red (chestnut auburn), black.

3. SIGHT.—(*a*) *Keenness of Eye-sight* is measured by the greatest distance at which the small print known as "diamond" type can be read.

The eyes are tested separately, as it often occurs that they differ

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considerably in efficiency without the person being aware of the fact, who ought in that case to use appropriate glasses.

The apparatus (Plate XII, fig. 1) is a long and light frame with a single eye-hole. Blocks of wood about $1\frac{1}{4}$ inch wide and $2\frac{1}{2}$ inches high, each with a sentence in diamond print pasted upon its face, are fastened square to the line of sight at distances of 7, 9, 11, and so on up to 41 inches. The number of inches is painted in bold figures on the upper part of the face of each block. The blocks are disposed in a curve, so that when viewed from the eye-hole each stands just clear of the preceding one (see fig. 1*a*); the curve of the frame is, in fact, an equiangular spiral. First the right eye is tested, and then the left eye, and the greatest distance at which the type can be read by each of them is recorded. If the print cannot be read at all by the unaided eye, a cross is marked on the schedule.

b. Colour-Sense.—A series of bars are packed closely side by side in a frame, looking something like the keys of a pianoforte. Fig. 2, Plate XII, shows only a portion of the instrument, as the right hand part has been broken off in order to exhibit its construction more distinctly. The two flaps are half opened for the same reason. When the upper flap is closed, the part B keeps the bars in an even row, and the part C nips their tops. When the lower flap is closed, the numbers on the bars are hidden. Along the middle part of each of these bars a differently coloured wool is wound lengthways, and the foot of each bar is stamped with a separate number. In the frame there are as many peg-holes as there are bars, one hole to each bar. The order of the bars can be changed when the instrument is unlocked. The frame is placed before the person to be tested, the numbers are hidden by the flap A, and he is required to insert a peg opposite each of the bars that has any shade of green wound round it. After he has leisurely done this to his satisfaction the attendant lifts up the flap and displays the numbers of the chosen colours, and records the fact of his having judged rightly or wrongly as the case may be.

c. Judgment of Eye as regards Length.—A board (Plate XIII, fig. 3) has two pairs of parallel strips of wood fastened across it, between each of which a bar slides freely. In each case a square rod, 15 inches long and somewhat longer than the bar, is hinged to it along its edges, and when closed down upon it, hides it altogether. There is a movable pointer attached to the lower of each pair of strips. The position of the pointers is shown in the figure, but the scale of the drawing is too small to show the slot and the rest of the easily-to-be-imagined arrangement by which they are rendered movable. In the one pair, the pointer is set somewhere about midway, and the person to be tested is desired to slide the rod until its middle is brought as nearly as he can judge opposite the pointer. When he has done this, the hinged rod is lifted and the face of the bar is exposed. This has a central fiducial mark, and bears graduations on either side of it each equal to $\frac{1}{100}$ of the total length of the rod. The error of adjustment is thus determined in percentage.

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The second rod has to be set so that the pointer shall correspond to one-third of its length, and the error of adjustment is similarly read off in units, each equal to a hundreth part of the total length of the rod.

As regards Squareness.—A board (Plate XIII, fig. 4), including a sector of a circle, has an arm movable about the centre of the circle, while a broad flap of which the last part is supposed in the figure to have been broken off, hides its free ends. A black line AB is drawn across the board. The person tested is desired to set the arm as squarely as he can to the black line. When he has done this, the attendant lifts the flap and exposes a scale of degrees graduated on the foot of the board, and reads off the error of the setting of the arm in degrees.

HEARING.—(*a*) *Its Keenness.*—Some apparatus is exhibited by which at least the relative acuteness of hearing can be tested; but it will not be used, as the noises and echoes of the building render such determinations untrustworthy.

(*b*) *Highest audible Note.*—An india-rubber tube communicates through 5 others with 5 fixed whistles of small bore, and of depths that will give 50, 40, 30, 20, and 10 thousand air vibrations in a second respectively—that is, of the several depths of 0·067, 0·084, 0·113, 0·169, and 0·380 inch. Each tube is nipped by a separate clamp. These are numbered in order, 5, 4, 3, 2, 1, and serve as keys. When any one of them is depressed, air is blown through the corresponding whistle, and is thrown into vibrations which can be heard by some as a shrill and pure note, while others hear merely a puff or nothing at all. Every person has his limits of power of hearing high notes, quite independently of the general acuteness of his hearing. The test lies in ascertaining which is the shrillest of the five notes that is audible. The precise limit of audible sound may be found by using a whistle that has a movable plug for its base. The larger of the small whistles are made by Messrs. Tisley & Co., 172, Brompton Road; the smaller and more delicate ones are made by Mr. Hawkesley, 357, Oxford Street.

TOUCH, &c.—Several instruments are exhibited, but it is not proposed to test with them, as the requisite time cannot be spared.

BREATHING CAPACITY.—A spirometer is used, made by a counterpoised vessel suspended in water. When the air is breathed into it through a tube, the vessel rises, and the scale at its side shows the number of cubic inches of displacement. The person to be tested fills his chest and expires deeply three or four times for practice, then, after a few seconds' rest, he tries the spirometer. Spirometers are usually furnished with a stop-cock to the breathing tube, which is intended to be closed when the expiration has ceased. An inverted glass syphon with a little water in it is connected with the breathing tube beyond the stop-cock. If the water does not stand at the same level in the two arms of the syphon it would show that the air in the spirometer was somewhat compressed or dilated as the case might be, and the air cylinder would have to be slightly adjusted before reading off. However, the error caused by neglect-

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ing this manometer rarely exceeds 4 cubic inches, and may be disregarded.

Swiftness of Blow.—A flat bar (Plate XIII, fig. 5) with a pad, P, at one end runs freely between guides. The blow is delivered with the fist straight at the pad, driving the rod nearly or quite home, or else the blow is converted into a pull by holding a stirrup attached to a string, and striking out into space. The stirrup is attached to a string or, better, to a piece of steel pianoforte wire which is looped round a catch that forms part of a little apparatus attached to the bar, and which is shown enlarged in fig. 5*a*. When the bar is in full motion the catch releases the string or wire, so that there is nothing to break. The swiftness of the motion of the bar is registered as follows:—Across its path a bridge is fixed and a flat steel rod projects from the bridge, lying above the bar and parallel to it. Its free end points in the same direction as that towards which the bar is driven by the fist. When the bar is set back ready for use, an arm, A, turning round a pin fixed in the framework is set so as to push the spring forcibly to one side, but as soon as the bar begins to move, a stud that is fixed to the bar strikes the arm from before it, and so releases the spring, which thereupon vibrates transversely to the moving bar. A pencil is attached to the spring, and the upper face of the bar carries a strip of the prepared cardboard used for white flexible slates. The pencil leaves a sinuous trace on the strip as shown in the lower figure, and the points where the trace crosses its own median line can be measured with precision. The spring that is used makes twenty-five complete vibrations in a second. Hence, if the interval between any two alternate crossing-points is 0·48 inch in length, the bar is travelling 1 foot per second. A scale is constructed of which the unit is 0·48 of an inch, and the graduations upon it are in feet per second. By applying this scale to the curve, the swiftness of the corresponding blow is immediately read off.

Strength (*a*) *of pull.*—The well-known instrument with a spring, dial, and pointer, made by Salter, is held as an archer holds his bow when in the act of drawing it, and the strength of the pull is given by the index.

(*b*) *Of squeeze.*—The instrument, also made by Salter, is tried first in the right hand, secondly, in the left hand.

Span of Arms.—A pair of rods, sliding over each other and with projections at either end, is held so that the tips of the fingers press against those projections; then the arms are extended to their full stretch. The graduations show the span.

Height (*a*) *above seat of chair.*—A quickly acting measuring-rod is fastened upright to the back of a solid and narrow chair.

(*b*) *Standing in shoes.*—This is taken by a measuring-rod fixed against the wall.

(*c*) The thickness of the heel of the shoe is measured.

Lastly *c* is subtracted from *b*, which gives—

(*d*) The height without shoes.

Weight.—A simple commercial balance is used, as cheaper, more

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accurate, and much more capable of bearing hard usage than the lever balances. Its sole disadvantage lies in the necessity of handling heavy weights during its use. Overcoats should be taken off, the weight required being that of ordinary indoor clothing.

Most of the instruments in use at the laboratory are wholly or in large part of my own designing. Those that are not are the spirometer, the instruments for testing strength of pull and of squeeze, and the weighing machine.

On the opposite page is a *fac simile* of the Schedule which was retained at the Anthropometric Laboratory. The card that was presented to each person examined was a duplicate of all the entries in the Schedule, except those printed crosswise at the right hand side.

Explanation of Plates XII and XIII.

(*For description, see both the Memoir and the Appendix to it.*)

Fig. 1. Instrument for testing keenness of sight.

„ 1*a*. Diagram showing how each of the blocks appears to stand just free of the preceding one when they are viewed through the eye-hole.

„ 2. Part of the apparatus for testing colour-sense by various samples of coloured wools. The right hand portion is supposed to be broken off.

„ 3. Apparatus for testing the accuracy of the judgment of the eye, in dividing a rod into two, and into three equal parts.

„ 4. Apparatus for testing the judgment of the eye as regards squareness. The left hand portion of a flap that conceals graduations is supposed to be broken off.

„ 5. Apparatus for testing swiftness of blow or pull.

„ 5*a*. Shows the mechanism of a self-acting catch, which releases the string by which the rod is pulled just before the rod comes home.

INTERNATIONAL HEALTH EXHIBITION, 1884.

ANTHROPOMETRIC LABORATORY,

Arranged by Francis Galton, F.R.S.

Sex | Colour of eyes

EYESIGHT.

	right eye	left eye
Greatest distance in inches, of reading "Diamond" type		

Colour-sense, goodness of

JUDGMENT OF EYE.

Error per cent. in dividing a line of 15 inches: in three parts | in two parts

Error in degrees of estimating squareness

HEARING.

Keenness can hardly be tested here owing to the noises and echoes.

Highest audible note: between 0·000 and 0·000 vibrations per second.

BREATHING POWER.

Greatest expiration in cubic inches

Date | Initials

SWIFTNESS

of blow of hand in feet per second

STRENGTH

of squeeze in lbs. of: right hand | left „ — of pull in lbs.

SPAN OF ARMS

From finger tips of opposite hands: feet, inches.

HEIGHT

Sitting, measured from seat of chair: feet, inches.

Standing in shoes: feet, inches.

less height of heel..... inches.

Height without shoes: feet, inches.

WEIGHT

in ordinary in-door clothing in lbs.

Age last birthday?

Married or unmarried?

Birthplace?

Occupation?

Residence in town, suburb, or country?

at the late International Health Exhibition.

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APPENDIX II.

THE value of the results obtained at the laboratory may be questioned on the ground that the persons who applied to be measured were not random specimens of the crowd who visited the Exhibition, and that the latter themselves were no fair sample of the British population, nor of any well-defined section of it. I have no reply to make to this objection, except that it should not be pushed unreasonably far. On the other hand, it may justly be claimed that results which, taken each by itself, have no great value as absolute determinations, may nevertheless be of considerable importance relatively to one another, by affording materials for testing the relations between various bodily faculties and the influences of occupation and birthplace. Their discussion in any form is a laborious task, and the portion of it that I now submit is very far indeed from exhausting the uses to which the laboratory records can be put. It deals mostly with the very results that I have just spoken of as being the least valuable; but I have taken them in hand first, because it was a necessary preliminary to any further discussion. I also wished to utilise the copious material at my disposal to exemplify what I trust will be found a convenient development of a method of statistical treatment I have long advocated, by presenting in a compact and methodical form (Table II) a great deal more concerning the distribution of the measurements of man than has hitherto been attempted in a numerical form.

The following brief summary of maximum measurements will be interesting:—

9,337 persons were measured, of whom 4,726 were adult males, and 1,657 adult females. The highest records during the whole time that the laboratory was open were those shown in Table I.

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TABLE I.

	Highest recorded cases among	
	4,726 Adult Males.	1,657 Adult Females.
Height without shoes, in inches	79·5	70·3
Weight, in lbs.	308	222
Breathing capacity, in cubic inches.. ..	354	270
Strength of pull, in lbs.	148	89
Strength of squeeze, in lbs.	112	86
Swiftness of blow, in feet per second ..	29	20
Sight distance, in inches, of reading diamond test-type	39	40

The meaning of Table II, and that of the new word "per-centile" which is defined in the heading to that Table, will be understood by the help of a single example, for which I will take the line referring to Strength of Squeeze among males. We see that a discussion was made of 519 measurements in that respect, of men whose ages ranged between 23 and 26; that 95 per cent. of them were able to exert a squeeze with their strongest hand (the squeeze was measured by a spring dynamometer) that surpassed 67 lbs. of pressure; that 90 per cent. could exert one that surpassed 71; 80 per cent. one that surpassed 76; and so on. The value which 50 per cent. exceeded, and 50 per cent. fell short of, is the Median Value, or the 50th per-centile, and this is practically the same as the Mean Value; its amount is 85 lbs. This line of the Table consequently presents an exact and very complete account of the distribution of strength in one respect among the middle 90 per cent. of any group of males of the tabular ages similar to those who were measured at the laboratory. The 5 per cent. lowest and the 5 per cent. highest cannot be derived directly from it, but their values may be approximately inferred from the run of the tabular figures, supplemented by such deductions as the Law of Error may encourage us to draw. Those who wish to apply this law will note that the "probable error" is half the difference between the 25th and the 75th per-centile, which can easily be found by interpolation, and they will draw the per-centiles that correspond respectively to the median value *minus* twice, three times, and three-and-a-half times the probable error, at the graduations 8·7, 2·4, 0·8, and those that correspond to the median value *plus* those amounts, at the graduations 91·3, 97·6, and 99·2. The Table is a mere statement of observed fact; there is no theory whatever involved in its construction, beyond simple interpolations between values that differ little from one another and which have been found to run in very regular series.

TABLE II.—ANTHROPOMETRIC PER-CENTILES.

Values surpassed, and Values unreached, by various percentages of the persons measured at the Anthropometric Laboratory in the late International Health Exhibition.

(The value that is unreached by n per cent. of any large group of measurements, and surpassed by 100-*n of them, is called its* nth *per-centile.)*

Subject of measurement.	Age.	Unit of measurement.	Sex.	No. of persons in the group.	Values surpassed by per-cents. as below. 95	90	80	70	60	50	40	30	20	10	5
					Values unreached by per-cents. as below. 5	10	20	30	40	50	60	70	80	90	95
Height, standing, without shoes ...	23–51	Inches	M.	811	63·2	64·5	65·8	66·5	67·3	67·9	68·5	69·2	70·0	71·3	72·4
			F.	770	58·9	59·9	61·3	62·1	62·7	63·3	63·9	64·6	65·3	66·4	67·3
Height, sitting, from seat of chair ...	23–51	Inches	M.	1013	33·6	34·2	34·9	35·3	35·4	36·0	36·3	36·7	37·1	37·7	38·2
			F.	775	31·8	32·3	32·9	33·3	33·6	33·9	34·2	34·6	34·9	35·6	36·0
Span of arms	23–51	Inches	M.	811	65·0	66·1	67·2	68·2	69·0	69·9	70·6	71·4	72·3	73·6	74·8
			F.	770	58·6	59·5	60·7	61·7	62·4	63·0	63·7	64·5	65·4	66·7	68·0
Weight in ordinary indoor clothes ...	23–26	Pounds	M.	520	121	125	131	135	139	143	147	150	156	165	172
			F.	276	102	105	110	114	118	122	129	132	136	142	149
Breathing capacity ...	23–26	Cubic inches	M.	212	161	177	187	199	211	219	226	236	248	277	290
			F.	277	92	102	115	124	131	138	144	151	164	177	186
Strength of pull as archer with bow	23–26	Pounds	M.	519	56	60	64	68	71	74	77	80	82	89	96
			F.	276	30	32	34	36	38	40	42	44	47	51	54
Strength of squeeze with strongest hand	23–26	Pounds	M.	519	67	71	76	79	82	85	88	91	95	100	104
			F.	276	36	39	43	47	49	52	55	58	62	67	72
Swiftness of blow... ...	23–26	Feet per second	M.	516	13·2	14·1	15·2	16·2	17·3	18·1	19·1	20·0	20·9	22·3	23·6
			F.	271	9·2	10·1	11·3	12·1	12·8	13·4	14·0	14·5	15·1	16·3	16·9
Sight, keenness of—by distance of reading diamond test-type ...	23–26	Inches	M.	398	13	17	20	22	23	25	26	28	30	32	34
			F.	433	10	12	16	19	22	24	26	27	29	31	32

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It may be used in many ways. Suppose, for example, that a man of the tabular age, viz., above 23 and under 26, and who could exert a squeeze of 80 lbs., desired to know his rank among the rest, the Table tells him at once that his strength in this respect certainly exceeds that of 30 per cent. of those who were measured, because if it had been only 79 lbs. it would have done so. It also tells him that his strength does not exceed that of 40 per cent. of the rest, since it would have required a pressure of 82 lbs. to have done this. He therefore ranks between the 30th and the 40th per-centile, and a very simple mental sum in proportion shows his place to be about the 33rd or 34th in a class of 100.

The Table exhibits in a very striking way the differences between the two sexes. The 5th male per-centile of strength of squeeze is equal to the 90th female per-centile, which is nearly but not quite the same as saying that the man who ranks 5th from the bottom of a class of 100 males would rank 10th from the top in a class of 100 females. The small difference between the two forms of expression will be explained further on. If the male per-centiles of strength of squeeze are plotted on ruled paper, beginning with the lowest, and if the female per-centiles are plotted on the same paper, beginning with the highest, the curves joining their respective tops will be found to intersect at the 7th per-centile, which is the value that 7 of the females and 93 of the males just surpass. Therefore, if we wished to select the 100 strongest individuals out of two groups, one consisting of 100 males chosen at random, and the other of 100 females, we should take the 100 males and draft out the 7 weakest of them, and draft in the 7 strongest females. Very powerful women exist, but happily perhaps for the repose of the other sex, such gifted women are rare. Out of 1,657 adult females of various ages measured at the laboratory, we have already seen that the strongest could only exert a squeeze of 86 lbs., or about that of a medium man. The population of England hardly contains enough material to form even a few regiments of efficient Amazons.

The various measurements of males surpass those of females in very different degrees, but in nearly every particular. A convenient way of comparing them in each case is that which I have just adopted, of finding the per-centile which has the same value when reckoned from the lower end of the male series, and from the higher end of the female series. When this has been done, the position of the per-centiles arranged in order of their magnitude are as follows:—Pull, 4; Squeeze, 7; Breathing capacity, 10; Height, 14; Weight, 26; Swiftness of blow, 26; Keenness of sight, 37. We conclude from them that the female differs from the male more conspicuously in strength than in any other particular, and therefore that the commonly used epithet of "the weaker sex" is peculiarly appropriate.

The Table was constructed as follows:—I had groups of appropriate cases extracted for me from the duplicate records by Mr. J. Henry Young, of the General Register Office. I did not care to

have the records exhausted, but requested him to take as many as seemed in each case to be sufficient to give a trustworthy result for these and certain other purposes to which I desired to apply them. The precise number was determined by accidental matters of detail that in no way implied a selection of the measurements. The summarised form in which I finally took them in hand is shown in the two upper lines of the following specimen:—

Height, Sitting, of Female Adults, aged 23–50, *in inches.*

29–	30–	31–	32–	33–	34–	35–	36–	37–	
2	8	52	116	226	227	108	31	5	Total 775
2	10	62	178	404	631	739	770	775	Abscissæ 0 to 775
30	31	32	33	34	35	36	37	38	Corresponding Ordinates.

The meaning of the two upper lines is that in a total of 775 observations there were 2 cases measuring 29 and under 30 inches, 8 cases measuring 30 and under 31 inches, and so on. The third line contains the sums of the entries in the second line reckoned from the beginning, and is to be read as follows:—2 cases under 30 inches, 10 cases (=2+8) under 31 inches, 62 cases (=2+8+52) under 32 inches, and so on.

I plotted these 775 cases on French "sectional" paper, which is procurable in long and inexpensive rolls, ruled crossways by lines 1 millimetre apart. I counted the first line as 0° and the 776th as 775°. Supposing the measurements to have been plotted in the order of their magnitude, in succession between these lines, the first would stand between 0° and 1°, the second between 1° and 2°, and so on. Now we see from the Table that the second measurement was just short of 30 inches, consequently the third measurement was presumably just beyond it, therefore the abscissa whose value is 2°, and which separates the second from the third measurement, may fairly be taken to represent the abscissa of the ordinate that is equal to 30 inches exactly. Similarly, the abscissa whose value is 10° divides the measurement that is just under 31 inches from that which is presumably just above it, and may be taken as the abscissa to that ordinate whose precise value is 31°, and so on for the rest. The fourth line of the Table gives the ordinates thus determined for the abscissæ whose values are entered above them in the third line. I dotted the values of these ordinates in their right places on the sectional paper, and joined the dots with a line, which in every case, except the breathing capacity, fell into a

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strikingly regular curve. (I shall speak further on about this one partial exception.) Per-centiles were then drawn to the curve, corresponding to abscissæ that were respectively 5 per cent., 10 per cent., 20 per cent., &c., of the length of the base line. As the length of the base line was 275, these per-centiles stood at the graduations 13·8°, 27·5°, 55·0°, &c. Their values, as read off on the sectional paper, are those which I have given in the Table.

It will be understood after a little reflection that the 9th rank in a row of 10, the 90th rank in a row of 100, and the 900th rank in a row of 1000, are not identical, and that none of them are identical with the 90th per-centile. There must always be the difference of one half-place between the post which each person occupies in a row of n individuals, numbered from 1 to n, and that of the corresponding graduation of the base on which he stands, and which bears the same nominal value, because the graduations are numbered from 0 to n and begin at a point one half-place short of the first man, and end at one half-place beyond the last man. Consequently the graduations corresponding to the posts of the 9th, 90th, and 900th man in the above example, refer to the distance of those posts from the beginning at 0 of their several base lines, and those distances are related to the lengths of the base lines in the proportions of 8·5 : 10, of 89·5 : 100, and of 899·5 : 1000, which when reckoned in per-cents. of the several base lines are 85, 89·5, and 89·95 respectively. The larger the number of places in the series, the more insignificant does this half-place become. Moreover, the intrusion of each fresh observation into the series separates its neighbours by almost double that amount, and propagates a disturbance that reaches to either end, though it is diminished to almost nothing by the time it has arrived there. We may therefore ignore the existence of this theoretically troublesome half-place in our ordinary statistical work.

There is a latent source of error that might affect such statistics as these, as well as many others that are drawn up in the usual way, which has not, so far as I know, been recognised, and which deserves attention. It is due to uncertainty as to the precise meaning of such headings as 30–, 31–, &c. If the measurements, no matter whether they were made carefully or carelessly, are read off from the instruments with great nicety, then a reading such as 30·99 would fall in the column 30–, and the mean of all the entries in such a column might fairly be referred to a mean value of 3·50.

But if the instruments are roughly read, say to the nearest half inch, the reading of a real instrumental value of 30·99, and even that of a real value of 30·76, would both be entered in the column 31–. The column 30– would then contain measurements whose real instrumental values ranged between 29·75 and 30·75, and the column 31– would contain those that ranged between 30·75 and 31·75; consequently, the means of all the entries in those columns

respectively should be referred, not to 30·5 and 31·5, but to 30·25 and to 31·25. Thus an error of a quarter of an inch in the final results might easily be occasioned by the neglect to note and allow for the degree of minuteness with which the instruments were read. No multiplication of measurements would get rid of it, neither would any increase of care in setting the instruments nor any increase in their accuracy. The error of which I speak is purely dependent on the degree of minuteness with which the instruments are read off. I strongly suspect that many statistical tables are affected by this generally unrecognised cause of error. The measurements at my laboratory were read to the nearest tenth of an inch and to a fraction of a pound, so I can afford to disregard this consideration. There was, however, a slight bias in favour of entering round numbers, which should have been, but were not (because I neglected to give the necessary instructions), rateably divided between the columns on either side.

I will now make a few remarks upon the measurements severally, and give some extracts from the numerous MS. tables already prepared, which I propose ultimately to present to the Anthropological Institute, together with the original laboratory records. They will form a valuable addition to those now in their possession, made by the Anthropometric Committee of the British Association, if utilised in connection with future inquiries into the influences of occupation and birthplace.

HEIGHT, STANDING *and* SITTING, *and* SPAN *of* ARMS *in* ADULTS.

A compendious view of the chief linear measurements of the persons examined is afforded by the three data: (1) height standing (without shoes); (2) height when sitting, measured upwards from the seat of the chair; (3) the span of the extended arms measured from the extreme finger tips. From these we can infer with approximate and adequate accuracy the lengths of the trunk, legs, and arms, and the proportion they severally bear to the total stature.

Height Sitting, and Span.

The ratio between height sitting and span varies as is well known during the period of growth, and is different in tall and short adults. The following table shows the relation between the two in persons of both sexes of approximately medium stature, who are between the ages of 23 and 51.

Height Sitting.			Span.		
Inches.	Males. Height 5 feet 8½ inches.	Females. Height 5 feet 3½ inches.	Inches.	Males. Height 5 feet 8½ inches.	Females. Height 5 feet 3½ inches.
31–	..	1	60–	..	3
32–	..	7	61–	..	4
33–	..	39	62–	..	31
34–	4	42	63–	..	23
35–	31	11	64–	..	19
36–	44	..	65–	1	10
37–	19	..	66–	2	3
38–	2	..	67–	3	..
..	..	..	68–	12	..
..	..	..	69–	18	..
..	..	..	70–	27	..
..	..	..	71–	22	..
..	..	..	72–	10	..
..	..	..	73–	3	..
..	..	..	74–	1	..
..	..	..	75–	1	..
	100	100		100	100

Height, Sitting and Standing.

As regards the ratio between height sitting and standing, it does not appear that a moderate increase of tallness in males is associated with a disproportionate increase of length of legs, the ratio of height sitting to height standing being uniform up to 6 feet or more. Its value is 54 : 100 ; in other words, the ratio of their legs to their trunk is 46 to 54 or thereabouts. When the stature exceeds 6 feet, the length of the legs as compared to that of the trunk increases notably ; but my cases are too few to warrant a numerical estimate. As regards females, the case is curiously different. Here an increase of stature is from first to last accompanied by an increase of the length of legs as compared to that of trunk. The data calculated as above are as follows :—For a female stature of 4 feet 10½ inches it is as 45 : 55, for 5 feet 2½ inches 46 : 50, and for 5 feet 6½ inches it is as 47 : 53. As regards taller females, my data distinctly point to a rapid progression in the rate of increase of the relation in question.

Weight.

As regards weight, I have nothing more to say at present.

Breathing Capacity.

The returns show a remarkable regularity in the alteration of the breathing capacity as life advances. It increases rapidly in early youth, and becomes stationary between the ages of 20 and 30

or a little later, and thenceforward steadily declines. I have already alluded to the existence of some irregularity in the run of the per-centiles of breathing capacity, in adults aged from 23 to 51. This is chiefly due, I think, to an unequal representation of the various ages between those limits, and to the somewhat irregular mixture of town and country folk, and of sedentary and active professions among the persons measured.

The following brief abstract gives a very fair epitome of the returns:—

AVERAGE BREATHING CAPACITY

(in cubic inches).

Ages.	Males.	Females.
10	135	121
15	199	138
20	216	142
25	217	137
30	213	137
35	211	136
40	203	123
45	194	119
50	191	118
55	178	111

The superior breathing capacity of the male is partly related to his stature and bulk; it is little in excess of that of females in early life, but becomes half as great again at the age of 20, and that large ratio is more than maintained throughout the whole of the after life.

Strength of Pull and Squeeze in Adults.

The strength of squeeze, as indicated by the instrument, does not keep ahead of that of pull at the highest end of the scale. The difference between them falls off, and is even reversed in the higher figures. I ascribe this wholly to the fault of the instrument, which does not permit the hand to act throughout with the same advantage. The more nearly it squeezes the bars together, the more it closes upon itself, and the less advantageously do the muscles act. It is easy to contrive an adjustment that might offer a similar grip in all cases, but it is not easy to construct one that shall act without additional loss of time. I have thought of a grip that should be forced by a steady increasing pressure, the strain at the moment of forcing it being registered automatically.

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Strength of the Right and Left Hands.

I had a batch of about 500 cases of males between the ages of 23 and 51 analysed to determine the relative strength of the right and left hands. Out of every 100 cases about 50 had the right hand strongest; 20, or rather more, had the left hand strongest; and in 30 the strength was the same. A single line out of the table will give a good idea of the whole. The total of the cases to which it refers was only 82, but for the convenience of percentages I have raised it to 100.

	Squeeze of the left hand (in lbs.)										
Squeeze of the right hand (in lbs.)	50–	55–	60–	65–	70–	75–	80–	85–	90–	95–	Total cases.
75–80.	1	1	6	9	26	27	21	6	2	1	100

On the average of all the cases the left hand appears to be about 6 per cent. weaker than the right hand.

While the figures were accessible, I thought it as well to see if by chance there existed any relation between the superior strength of the right or left hand and the superior reading power, as explained farther on, of the right or left eye. There was absolutely none. Had I had means to compare the inferior skill of the right or left hand, which I had not, the existence of some relation would be less improbable.

Strength of Squeeze and Breathing Capacity.

I was surprised to find that there is no close relation between strength of squeeze and breathing capacity. As the measurements are peculiarly trustworthy, being all made with the same instruments and by the same observers, I give the records in full to establish the fact. The importance of a large breathing capacity to a man who expends force rapidly, as to a runner or a mountain climber, is undoubted, but for a strain of short duration it seems comparatively non-essential. Still, I should have thought it to have been more nearly connected with every form of strength than it is. The table shows that an increase of breathing capacity from 150 to 300 inches is accompanied by an increase of strength of squeeze from an average of 75 lbs. to not more than 92 lbs. That is to say, when the breathing capacity is double, the strength of squeeze is on the average only one quarter greater.

BREATHING CAPACITY AND STRONGEST SQUEEZE.—Males, age 23, 24, and 25.

Breathing capacity.	STRONGEST SQUEEZE IN LBS.															
	45–	50–	55–	60–	65–	70–	75–	80–	85–	90–	95–	100–	105–	110–	115–	Total.
Cubic inches.																
70–80	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	1
100	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
110	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	1
120	..	..	..	..	1	..	1	..	..	..	..	..	..	..	..	2
130	..	..	..	..	1	..	1	..	..	..	..	..	..	..	..	2
140	..	..	1	..	1	..	1	..	..	..	..	..	..	..	..	3
150	..	..	1	..	1	3	1	1	..	1	..	1	..	..	..	9
160	..	..	..	1	2	3	4	2	1	2	..	..	..	..	..	15
170	..	..	..	..	1	3	7	6	3	1	1	..	..	..	..	22
180	..	..	1	3	3	9	10	6	6	3	1	1	1	..	..	44
190	..	..	1	..	..	4	6	10	3	2	3	2	..	1	..	32
200	..	..	..	1	1	10	7	9	8	9	3	..	1	..	..	49
210	..	..	..	1	4	2	9	11	7	6	5	3	3	..	..	51
220	..	..	..	1	4	6	11	12	11	6	10	4	..	..	..	65
230	..	..	1	1	3	1	6	6	13	5	9	1	2	1	..	49
240	..	..	..	..	1	5	4	10	10	8	7	2	1	..	..	48
250	..	..	..	1	..	1	2	4	8	4	4	3	2	..	..	29
260	..	..	..	..	1	2	3	1	7	4	4	1	..	..	..	23
270	..	..	..	..	..	..	2	3	5	1	2	1	..	1	..	15
280	..	..	..	..	..	..	2	2	1	2	4	3	2	1	..	17
290	..	..	..	..	..	..	..	2	3	7	4	2	1	1	..	20
300	..	..	..	..	1	..	3	2	3	6	2	1	..	..	..	18
310	..	..	..	..	..	..	..	..	1	..	1	1	..	..	..	3
320	..	..	..	..	..	..	..	..	1	..	..	1	1	..	..	3
330	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
340	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1
..	..	..	5	9	26	49	80	88	91	67	60	28	14	5	..	522

† 19v

f. 17c

Eyesight.

The light at the laboratory was rarely sufficient, and it was very variable, since the tests were carried on partly in the daytime, partly when the light was waning, and partly during the evening illumination. The absolute results are therefore of little importance, though they are worth recording, namely, that one quarter of the males of various ages who were able to read small print at all without glasses, were able with one eye to read pages taken from the well-known little shilling prayer-book, printed in diamond type, at a greater distance than 27 inches, one-half of them at a greater distance than 22 inches, and three-quarters at a greater distance than 18 inches. No person at the laboratory succeeded in reading a page further off than 38 inches, though one lady at my own house, probably under better light and using both her eyes, unmistakably exceeded 41 inches.

Though the tests are of little importance absolutely, they are of much value relatively in comparing the power of the two eyes, as to whether on the whole the right eye is stronger than the left, or *vice versâ*, and what is the average difference between their powers. It appeared from an examination of about 850 cases that the number of those whose two eyes were equally effective bore the ratio of 2 to 3 (or a very little more than 3) to the number of those in whom the powers of the two eyes differed to a notable degree. It also appeared, on taking the average of all the 850 cases, that the difference between the greatest reading distance of the two eyes with the above test type, was just 2 inches (or the merest trifle less). And lastly, it appeared that the average strength of the right and of the left eyes was almost exactly the same. Thus with the right eye there were 253 cases in which the greatest reading distance lay between 20 and 24 inches, and with the left eye there were 256 such cases; again, when the greatest distances lay between 25 and 29 inches, the cases were 229 and 224 respectively.

I have nothing of novelty to say regarding the colour sense, as the data, although they have been tabulated, have not yet been discussed.

Highest Note Audible.

The measurements were made with five whistles set to emit 10, 20, 30, 40, and 50 thousand vibrations per second respectively. Notwithstanding the roughness of the measurements, the results fall into a very fair curve; however, it would be hardly justifiable to give per-centiles, because the values on which the curve is based are wide apart. I therefore limit myself to giving a table of the actual observations reduced to percentages for the convenience of comparison. It will be seen here, as in every other faculty that has been discussed, the male surpasses the female; 18 per cent. of the males hear the shrillest test-note, as against 11 per cent. of the

females, and 34 per cent. of the males hear the next shrillest test-note, as against 28 per cent. of the females.

	Ages.	Percentage of cases in which the under-mentioned number of vibrations were perceived as a musical note.				Number of Cases.
		Number of vibrations per second.				
		20,000	30,000	40,000	50,000	
Males..	23–26	99	96	34	18	206
	40–50	100	70	13	4	317
Females	23–26	100	94	28	11	176
	40–50	100	63	8	1	284

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